TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

GEOPHYSICAL TECHNOLOGY LIMITED (G-TEK) – SUB-AUDIO MAGNETICS (SAM)/SLING – *WOODS SCORING RECORD NO. 381*

The Sub-Audio Magnetics (SAM) in the sling platform is shown being demonstrated by G-Tek.

The Sub-Audio Magnetics (SAM) in the sling platform was demonstrated by G-Tek at the Aberdeen Proving Ground Standardized Demonstration Site's Woods Area. This technical paper contains the results of that demonstration. This is a reference document only and does not serve as an endorsement of the demonstrator's product by the US Army or the Standardized UXO Technology Sites Program.

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Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland and Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Center (USAEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP) and the Army Environmental Quality Technology Program (EQT).

DEMONSTRATOR'S SYSTEM AND DATA PROCESSING DESCRIPTION

Sub-Audio Magnetics (SAM) is a method by which a total field-magnetometer Magnetic Intensity (TMI) and Total Field Electromagnetic Induction (TFEMI) data. The SAM system consists of a Magnetometer, an Electro-magnetic Transmitter and Data Positioning Systems.

The SAM capable TM-6 magnetometer to be used has been developed and built by G-TEK. Its salient features include: accepting Larmor signal input from a hand-held array of four optically pumped magnetic sensors, simultaneously acquiring magnetic field measurements from each sensor at selectable rates up to 4,800 per second, acquiring measurements at precise intervals of time in synchronization with Global Positioning System (GPS) time, accepting position and time information including 1-pps strobe from Differential Global Positioning System (DGPS), and graphic user interface implemented on a Pocket PC. The root-mean-square (RMS) noise floor for each measurement sample rate typically lies between 1 nT at 10,000 per second to 1 pT at 100 per second when plotted on a logarithmic abscissa. In this program we propose sampling at 4,800 per second where the noise is approximately 0.2 nT, reducible in late-time by the averaging of consecutive samples. The magnetometer, DGPS, and batteries to power a quad-sensor array for 2.5 hours are carried in a backpack weighing about 8 kg.

The SAM system also consists of an Electromagnetic Transmitter in which an eight-turn wire loop is laid out along a meandering path that surrounds the grid area to be surveyed (typically 33 by 33 m). A Zonge GGT-10 current transmitter energizes this loop with a bipolar, 12- to 20-amp square wave current usually of 50 percent duty cycle and 15 Hz frequency. The transmitter and receiving

magnetometer are precisely synchronized using GPS time.

The TM-6 magnetometer system has been designed to interface with a variety of Data Positioning Systems as different application localities have different characteristics and requirements. There is a requirement when using the magnetometer for SAM applications that access is available to GPS time at least once every 30 minutes in order to maintain precise clock synchronization. However, this time signal may be obtainable in conditions such as wooded areas where DGPS positional accuracy is not satisfactory. In such situations, a cotton thread based odometer system developed by G-TEK and used for more than 25 years, provides a good alternative. However, emerging new technologies such as the Robotic Total Station (RTS) have been allowed for in the design of the magnetometer. At the APG site it is proposed that both the odometer and RTS will be used in the forested area for the purpose of evaluating their relative performance.

Performance Summary

Results for the Woods test broken out by size, depth and nonstandard ordnance are presented in the table below. Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range. The results are relative to the number of ordnance items emplaced. Depth is measured from the geometric center of anomalies.

The Response Stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the Discrimination Stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90 percent confidence limit on probability of detection and Pfp was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

Summary of Wooded Results for the SAM/Sling (EM Sensor)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Low 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Upper 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_{fp}	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Low 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Upper 90% Conf	NA	-	-	-	-	-	NA	NA	NA
BAR	NA	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Low 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Upper 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_{fp}	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Low 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Upper 90% Conf	NA	-	-	-	-	-	NA	NA	NA
BAR	NA	-	-	-	-	-	-	-	-

Summary of Wooded Results for the SAM/Sling (Mag Sensor)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
FERROUS ONLY GROUND TRUTH									
RESPONSE STAGE									
P_d	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Low 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Upper 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_{fp}	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Low 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Upper 90% Conf	NA	-	-	-	-	-	NA	NA	NA
BAR	NA	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Low 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Upper 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_{fp}	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Low 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Upper 90% Conf	NA	-	-	-	-	-	NA	NA	NA
BAR	NA	-	-	-	-	-	-	-	-
FULL GROUND TRUTH									
RESPONSE STAGE									
P_d	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Low 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Upper 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_{fp}	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Low 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Upper 90% Conf	NA	-	-	-	-	-	NA	NA	NA
BAR	NA	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Low 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_d Upper 90% Conf	NA	NA	NA	NA	NA	NA	NA	NA	NA
P_{fp}	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Low 90% Conf	NA	-	-	-	-	-	NA	NA	NA
P_{fp} Upper 90% Conf	NA	-	-	-	-	-	NA	NA	NA
BAR	NA	-	-	-	-	-	-	-	-

Response Stage Noise Level: NA
Recommended Discrimination Stage Threshold: NA

Note: *G-Tek only provided results for the combined EM/MAG for this specific demonstration.*

Summary of Wooded Results for the SAM/Sling

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.10	0.10	0.10	0.00	0.20	0.30	0.10	0.10	0.05
P_d Low 90% Conf	0.08	0.08	0.04	0.00	0.12	0.17	0.07	0.07	0.01
P_d Upper 90% Conf	0.15	0.18	0.18	0.04	0.28	0.47	0.17	0.19	0.21
P_{fp}	0.35	-	-	-	-	-	0.30	0.40	0.30
P_{fp} Low 90% Conf	0.31	-	-	-	-	-	0.26	0.34	0.19
P_{fp} Upper 90% Conf	0.37	-	-	-	-	-	0.35	0.42	0.42
BAR	0.15	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.05	0.10	0.05	0.00	0.10	0.15	0.10	0.05	0.00
P_d Low 90% Conf	0.04	0.05	0.01	0.00	0.06	0.06	0.05	0.03	0.00
P_d Upper 90% Conf	0.10	0.13	0.09	0.04	0.19	0.30	0.13	0.13	0.13
P_{fp}	0.10	-	-	-	-	-	0.10	0.10	0.05
P_{fp} Low 90% Conf	0.08	-	-	-	-	-	0.07	0.08	0.02
P_{fp} Upper 90% Conf	0.12	-	-	-	-	-	0.13	0.14	0.15
BAR	0.05	-	-	-	-	-	-	-	-

Response Stage Noise Level: -4.84
Recommended Discrimination Stage Threshold: 0.99

Note: *The recommended discrimination stage threshold values are provided by the demonstrator*

To view the full Scoring Record for this demonstration and for all other demonstrations conducted at the Aberdeen and Yuma Proving Grounds in support of the Standardized UXO Technology Demonstration Sites Program please visit our Web site at: www.uxotestsites.org.